CHEMICAL ENGINEERING

DISTINGUISHED YOUNG SCHOLARS SERIES

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PhD
North Carolina State University

Stimuli-Responsive Polymers

ABSTRACT: Folding and bending are common phenomena found in nature, prominent in the formation of structures ranging from plants to proteins. In addition, research has shown that materials can be made to autonomously change their shape from planar materials into functional, three-dimensional objects. By harnessing this potential of man-made materials, self-folding structures have applications in everything from biomedical to aerospace engineering. Different materials are chosen for these applications based on their mechanical properties and the variety of external stimuli with which they can be activated. The work presented here implements both rigid (Young's modulus ~1 GPa) and soft (Young's modulus ~ 0.1 MPa) polymer materials to generate devices ranging from grippers to artificial muscles.

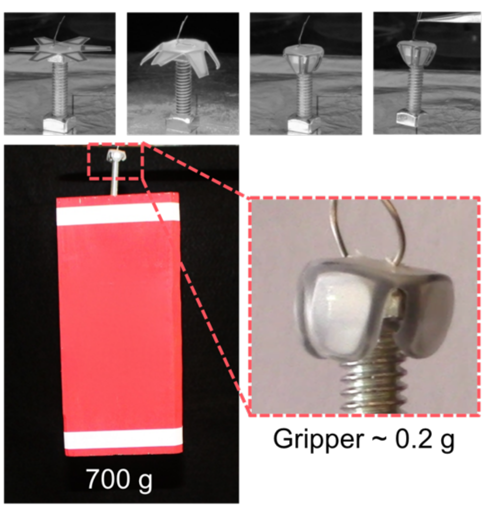

Figure 1. Grippers form from planar, polymer materials within ~5 seconds upon exposure to IR light and demonstrate significant strength

A variety of polymers including thermoplastics, hydrogels, and elastomers are presented here as viable materials for stimuli-responsive devices. Thermoplastics implemented herein are strained polystyrene and poly(methyl methacrylate). Material strain is locally released by exposure to an infrared light or heat gun for controlled heating above the glass transition temperature (Tg), resulting in controlled out-of-plane folding and bending of the sheets. Thermoplastics, rigid polymer materials, are shown transforming from planar sheets into complex geometries such as spheres or grippers within seconds of exposure to an IR light source as seen in Figure 1. Gripper devices demonstrate the ability to withstand loads >24,000 times their own mass.

Similar out-of-plane movement is realized with flexible polymers by generating polyampholyte hydrogel/elastomer composites. The composites are bound to a fabric interphase of glass fiber fabric acting as an interfacial compatibilizer between the gels. By exposing the laminate composites to organic solvents and salt solutions, the gels selectively swell or de-swell resulting in controlled curvature (cf., Figure 2). Hydrogel and elastomeric composites are shown transforming from planar laminates into curved structures for applications such as actuators. These composites demonstrate a synergistic increase in Young's modulus of the composite (~1.2 GPa) as compared to the individual gels (~0.1-1.3 MPa). Meanwhile, the composites exhibit a low bending modulus (~7 MPa), prompting its application as an artificial muscle with an actuation stress ~20% that of human skeletal muscle.

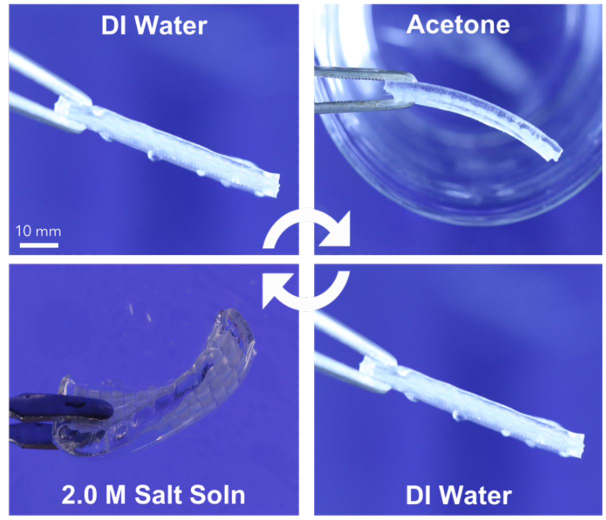

Figure 2. Hydrogel/elastomer composites function as triple state actuators based on varying environmental conditions.

BIOGRAPHY: Amber received her Bachelor of Chemical Engineering degree from Auburn University in 2014 with a specialization in Biomedical Engineering. She conducted undergraduate research under the supervision of Dr. Virginia Davis studying the dispersion state of carbon nanomaterials during her time at Auburn. Upon graduation, Amber began attending North Carolina State University pursuing her PhD in Chemical and Biomolecular Engineering as a National Science Foundation (NSF) Graduate Research Fellow. She received her MS in the Fall of 2016 and recently defended her PhD in May of 2019 under the supervision of Professors Michael Dickey and Jan Genzer. Amber's primary research interests are centered around stimuli-responsive thermoplastic polymers and their use in functional devices such as grippers or remote deployment systems. In addition, as a joint NSF and Japan Society for the Promotion of Science (JSPS) Research Fellow, Amber completed an academic internship by working in the Laboratory of Soft and Wet Matter. This five-month internship was under the supervision of Professor Jian Ping Gong at Hokkaido University in Sapporo, Japan. Amber's primary focus during this internship was in generating hydrogel/elastomer composites for enhanced mechanical properties and artificial muscle applications. Amber is particularly passionate about international collaborations, scientific photography (i.e., using visua aids to communicate technical material to non- technical audiences), and mentoring undergraduate students.

LECTURE 4:00 – 5:00 (PAA) A118
Happy Hour in Benson Hall Lobby Following